ANOMALIES OF THE PULMONARY ARTERY IN NECTURUS.

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The specimens of *Necturus maculosus* (Raf.) to be described in this paper are adult animals, which have been injected through the ventral aorta with red starch mass. The injections may be called good, since the main arterial vessels and their branches are well distended. None of the specimens show any evidence that the pulmonary circulation has been disturbed through injury or pathological condition.

In the first case the arteries are arranged as shown in Fig. 1. The right side of the animal is normal. Here the pulmonary artery arises from the combined portion of the second and third efferent aortic arches. On its way to the lung it sends small branches to the muscles of the pectoral region.[1] These are comparable with the large cutaneous branch of the pulmonary artery in the frog.[2] After sending out the pectoral branches, the pulmonary artery of Necturus, as described by Miller, "passes across the dorsal surface of the lung to gain its dorso-mesial side, along which it runs, gradually diminishing in size, to its tip."[3] This normal condition is found on the right side.

The left lung of the Necturus shown in Fig. 1 receives its blood at its extreme distal end. The supply is from a large seventh intercostal trunk, which appears at the level of the twelfth vertebra, posterior of the celiac artery. This intercostal vessel divides at once on

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[1] These branches have been described by W. S. Miller in "The Vascular System of *Necturus maculatus*." Bull. Univ. Wisconsin, No. 33, pp. 213-214.

[2] Ecker, A. The Anatomy of the Frog. (Translated by G. Haslam.) 1889, p 229, Fig. 149.

[3] Miller, William S. The Blood and Lymph Vessels of the Lung of Necturus maculatus. Amer. Journ. Anat., 1905, Vol. IV, p. 446.

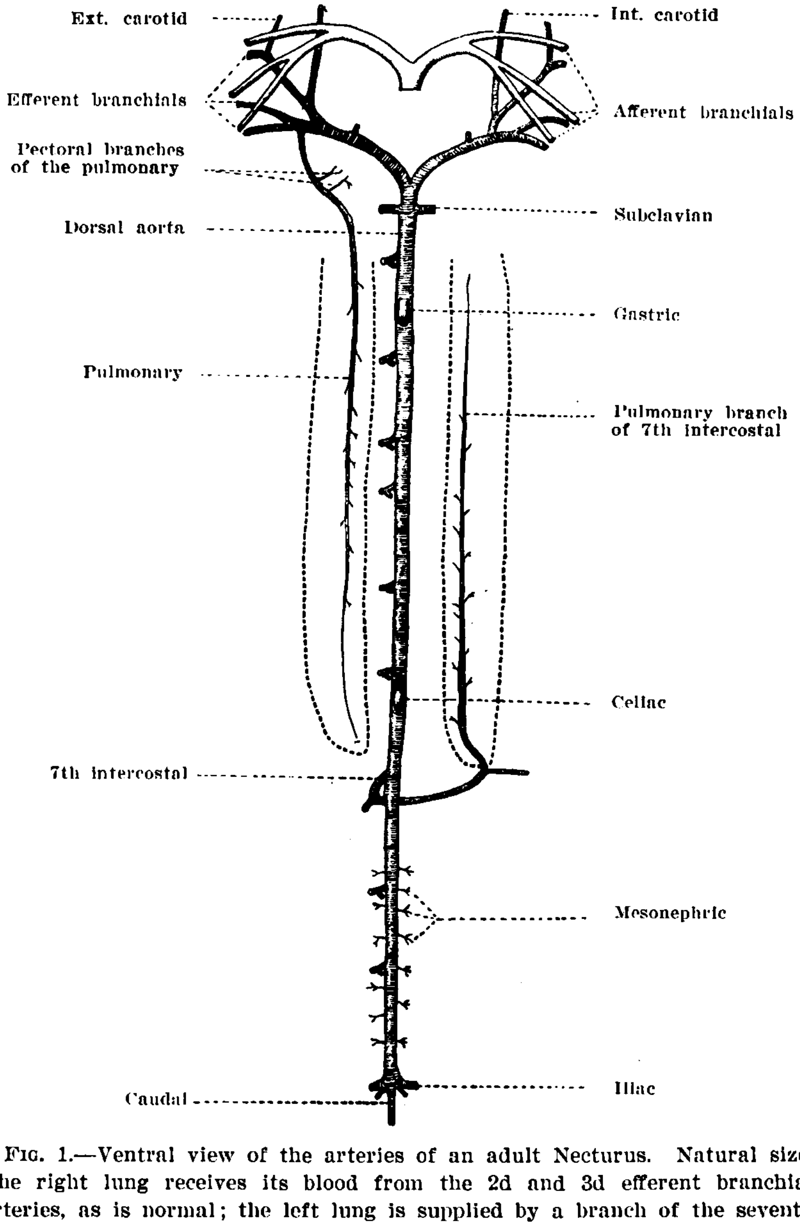

FIG. 1.—Ventral view of the arteries of an adult Necturus. Natural size. The right lung receives its blood from the 2d and 3d efferent branchial arteries, as is normal; the left lung is supplied by a branch of the seventh intercostal artery.

leaving the aorta and is so turned that both divisions are on the right side. The left branch, which is much larger, turns towards its own side dorsal to the aorta. It is entirely free from the musculature until after it has branched. The larger portion then enters the left lung near its tip and runs forward along its ventro-mesial side. The remainder of the vessel, reduced to less than one-third of its previous size, penetrates the musculature of the left side of the body about 5 mm. laterally from the tip of the lung.

This pulmonary vessel appears as the reverse of the normal artery, since it runs anteriorly from the tip toward the base of the lung. It gives off lateral branches alternately, and grows smaller and smaller until the starch mass can penetrate no farther. Beyond this point a fine line, due to the presence of clotted blood, indicates the continuance of the vessel for a short distance. The diminution and stopping of the injected vessel while on the lung, and the absence of any starch mass starting from the fully injected aortic arch, indicate that there is no vessel at all comparable with the normal proximal end of the pulmonary artery. It is quite possible, however, that it is represented by capillary connections.

This extraordinary anomaly may be readily explained through embryological development. It is generally believed that after the vascular system has become established in very young embryos, all subsequent vessels arise from it as offshoots. Where there is a connective tissue pathway, a branch from a neighboring vessel is likely to enter it and to anastomose with such other vessels as it encounters. If a favorable channel results, the small vessel becomes a main channel.[4] A striking illustration of this mode of development has recently been supplied by Spalteholz.[5] It has been known for some time that in certain reptiles a bridge of connective tissue extends from the tip of the heart across the pericardial cavity to the thoracic wall. Spalteholz has shown that a branch of the adjacent internal mammary artery may enter this bridge and extend to the heart, thus becoming a coronary artery. The heart may receive its blood supply from its apex as well as from its base provided that the connective tissue pathway is present. In the lung of Necturus the mesentery is the connective tissue path, although a slender and apparently unfavorable one. In the specimen under discussion either a branch of the pulmonary artery passed out from the lung to anastomose with the intercostal artery, or a branch of the latter entered the lung and joined the pulmonary branches. That both of these processes occur is suggested by the following variations.

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[4] This conception of vascular development was advocated by F. T. Lewis at the meeting of American Anatomists in 1903, and by H. E. Evans at their last session, in 1908.

[5] Spalteholz, W. Zur vergleichenden Anatomie der Aa. coronariae cordis. Verh. der. anat. Gesellschaft, 1908, pp. 169-180.

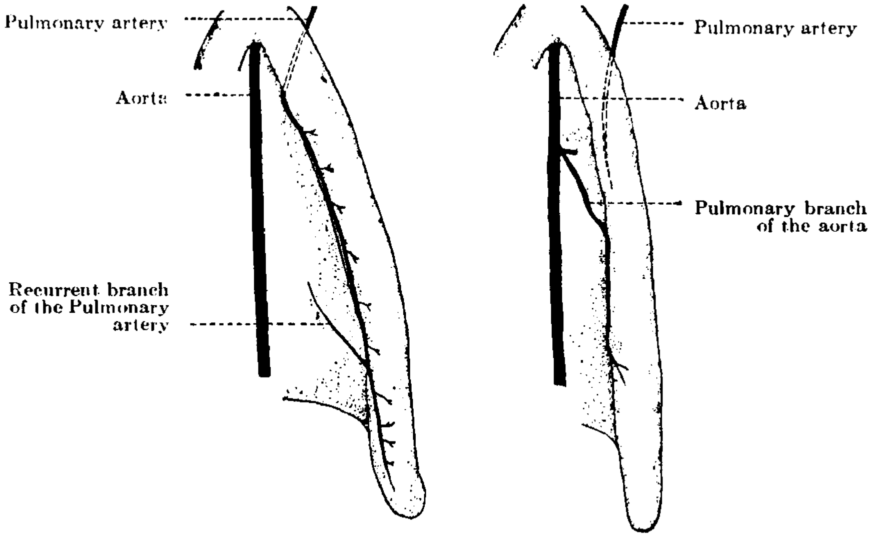
Pulmonary artery
Aorta
Recurrent branch of the Pulmonary artery
Pulmonary artery
Aorta
Pulmonary branch of the aorta

Fig. 2. Fig. 3.

Figs. 2 and 3.—Variations in the pulmonary arteries in the left lung of Necturus. 2/3 natural size.

Fig. 2 represents a left lung, 100 mm. in length, which is free from the mesentery along its distal 20 mm. At a point 9 mm. before the lung becomes free, at the level of the middle of the eleventh vertebra, a fairly large branch passes from the pulmonary artery toward the median line. It is enclosed in the mesentery. This branch tapers gradually without forking, and terminates without making demonstrable connections with other vessels. It clearly conveyed a stream of blood away from the lung. In the case shown in Fig. 3, however, the dorsal aorta sends a branch to the left lung which supplies its distal two-thirds.[6] Here the current of blood is toward the distal end of the lung instead of away from it as in Fig. 2.

All three of these variations may be explained on the basis of embryonic capillary connections between the dorsal aorta and the pulmonary artery. Although such connections have not yet been observed in Necturus embryos, they may be confidently predicted. They have already been found by Dr. Evans in chicks incubated from sixty to seventy hours. It will be remembered that in the human adult, branches of the bronchial artery, which comes from the aorta, have been said by several investigators to anastomose with the pulmonary artery in the lung. Miller and others are unable to find such connections.[7] But Nicolas[8] has stated that "it appears well established that the pulmonary arteries (of man) anastomose with the bronchial arteries not only through a capillary network, but also by branches which are quite large, and which may attain a diameter of 0.5 mm. or more." Detached portions or "accessory lobes" of the human lung are sometimes supplied entirely by a branch of the thoracic aorta, and are drained by veins emptying into the azygos system. Simpson[9] described such a case in a child at birth, and found records of two others, occurring at three months and eighteen years respectively. In one case the artery to the accessory lobe left the aorta at the level of the seventh thoracic vertebra; in the other two it was at the level of the tenth vertebra. This is comparable with the arrangement in the abnormal Necturus.

Abnormal vessels entering the lung of the frog, near its apex, have been found by several observers. The veins have received more attention than the arteries. T. W. Shore has figured two cases, in one of which a branch of the renal portal vein, and in the other a branch of the heptatic portal vein entered the lung.[10] E. Warren[11] had previously described and figured three similar cases, in one of which a branch of the renal portal vein joined a branch of the hepatic portal, and the resulting trunk entered the left lung near its apex. In this case it is recorded that a branch of the posterior mesenteric artery accompanied the vein into the lung, and the figure indicates that it anastomosed with a normal pulmonary artery. Warren states that "this arrangement of blood-vessels is strikingly similar to that seen in a teleostean fish, where an artery runs from the mesenteric artery into the rete mirabile of the air-bladder, and from there the blood is carried by a vein into the portal system." But he hesitated very properly before interpreting the anomaly in the frog as a reversion to a fish-like ancestor. G. P. Mudge[12] recorded still another case occurring in the frog. A branch of the celiac artery entered the right lung and two branches of the superior mesenteric artery entered the left lung. On both sides the arteries were accompanied by branches of the portal vein. Mudge states that in Ophidia Hyrtl found secondary pulmonary arteries arising from the aorta and the arteries of the liver, œsophagus, and stomach; the corresponding veins entered the portal system. Mudge concludes with the following statement: "Whether the close correspondence between the remarkable condition herein described as abnormal for the frog and that apparently normal for certain ophidians be indicative of anything more than mere coincidence, further investigation can alone determine."

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[6] The dissection and sketch of this specimen were made by Dr. F. T. Lewis when studying with me in the zoological laboratory in Cambridge. I am indebted to him for the memorandum concerning it.

[7] Miller, William S. The Arrangement of the Bronchial Blood vessels. (Preliminary Communication.) Anat. Anz., 1906, Vol. 28, pp. 432-436.

[8] Nicolas, A. See Poirier's Traité d'Anatomie Humaine, Paris, 1895, Vol. IV, p. 528.

[9] Simpson, G. C. E. A case of accessory lobe of the right lung. Journ. Anat. and Phys., 1908, Vol. 42, pp. 221-225.

The results of further investigation indicate that the occurrence of pulmonary branches of the aorta in the various classes of vertebrates has an embryological rather than an evolutionary significance. The connective tissue pathway being provided, capillary branches from the adjacent vessels will enter it, and occasionally, as in these Necturus specimens, certain of them will become very large, and notable as anomalies.

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[10] Journ. Anat. and Phys., 1901, Vol. 35, pp. 323-329.

[11] Anat. Anz., 1900, Vol. 18, pp. 122-123.

[12] Journ. Anat. and Phys., 1898, Vol. 33, pp. 54-63.